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Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for air-purification performance of semiconducting photocatalytic materials under indoor lighting environment —

Part 2: Removal of acetaldehyde

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Foreword

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The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see www.iso.org/directives).

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For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT) see the following URL: www.iso.org/iso/foreword.html.

This document was prepared by Technical Committee ISO/TC 206, *Fine ceramics*.

A list of all parts in the ISO 17168 series can be found on the ISO website.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at www.iso.org/members.html.

Introduction

Photocatalyst is a substance that performs decomposition and removal of contaminants, self-cleaning, antifogging, deodorization and antibacterial actions under photoirradiation. Its application has expanded considerably in recent years. The application of photocatalysts for indoor spaces has increasingly been sought as a solution to indoor environmental problems. Since conventional photocatalysts are responsive only to ultraviolet light, studies have been made to develop an indoor-light-active photocatalyst that makes effective use of indoor light, which room lights mainly emit, and thus demonstrates high photocatalytic performance indoors. The development has recently led to the commercialization of various indoor-light-active photocatalytic products, and there has been demand for the establishment of test methods to evaluate the performance of this type of photocatalyst.

This document, with ISO 17168-1 as the basis, is intended to provide a testing method to determine the performance of indoor-light-active photocatalytic materials with regards to the removal of acetaldehyde, a representative lower aliphatic volatile organic compound (VOC), enabling swift distribution of photocatalytic products and thus contributing to a safe and clean environment.

Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for air-purification performance of semiconducting photocatalytic materials under indoor lighting environment —

Part 2: Removal of acetaldehyde

1 Scope

This document specifies a test method for the determination of the air-purification performance, with regards to removal of acetaldehyde, of materials that contain a photocatalyst or have photocatalytic films on the surface, usually made from semiconducting metal oxides such as titanium dioxide or other ceramic materials, by continuous exposure of a test piece to the model air pollutant under illumination from indoor light.

This document is intended for use with different kinds of materials, such as construction materials in flat sheet, board or plate shape, which are the basic forms of materials for various applications. This document also applies to materials in honeycomb form, and to plastic or paper materials containing ceramic microcrystals and composites. This document does not apply to powder or granular photocatalytic materials.

This test method is usually applicable to photocatalytic materials produced for air purification. This method is not suitable for the determination of other performance attributes of photocatalytic materials, i.e. decomposition of water contaminants, self-cleaning, antifogging and antibacterial actions.

2 Normative references

The following documents are referred to in the text in such a way that some or all of their content constitutes requirements of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 4224, *Ambient air — Determination of carbon monoxide — Non-dispersive infrared spectrometric method*

ISO 6145-7, *Gas analysis — Preparation of calibration gas mixtures using dynamic volumetric methods — Part 7: Thermal mass-flow controllers*

ISO 14605, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Light source for testing semiconducting photocatalytic materials used under indoor lighting environment*

ISO 16000-3, *Indoor air — Part 3: Determination of formaldehyde and other carbonyl compounds in indoor air and test chamber air — Active sampling method*

ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

ISO 17168-1, *Fine ceramics (advanced ceramics, advanced technical ceramics) — Test method for air purification performance of semiconducting photocatalytic materials under indoor lighting environment — Part 1: Removal of nitric oxide*

ISO 80000-1, *Quantities and units — Part 1: General*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO 17168-1 apply.

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

— ISO Online browsing platform: available at https://www.iso.org/obp

— IEC Electropedia: available at http://www.electropedia.org/

4 Symbols

f	air-flow rate converted into that at the standard state (0 °C and 101,3 kPa) (l/min)
ϕ_A	acetaldehyde volume fraction at the reactor exit (µl/l)
ϕ_{AD}	acetaldehyde volume fraction at the reactor exit under dark conditions (µl/l)
ϕ_{A0}	volume fraction of acetaldehyde in the test gas (µl/l)
ϕ_{CO2}	CO_2 volume fraction generated by indoor-light irradiation (µl/l)
$\phi_{CO2,L}$	CO_2 volume fraction at the reactor exit under indoor-light irradiation (µl/l)
$\phi_{CO2,D}$	CO_2 volume fraction at the reactor exit under dark conditions (µl/l)
$\phi_{CO2,Dpost}$	CO_2 volume fraction in the dark before indoor-light irradiation (µl/l)
$\phi_{CO2,Dpre}$	CO_2 volume fraction in the dark after indoor-light irradiation (µl/l)
n_A	quantity of acetaldehyde removed by the test piece (µmol)
n_{CO2}	quantity of CO_2 converted from acetaldehyde per hour (µmol/h)
R_A	removal percentage, by test piece, of acetaldehyde (%)
R_{CO2}	conversion from acetaldehyde to CO_2 (%)

5 Principle

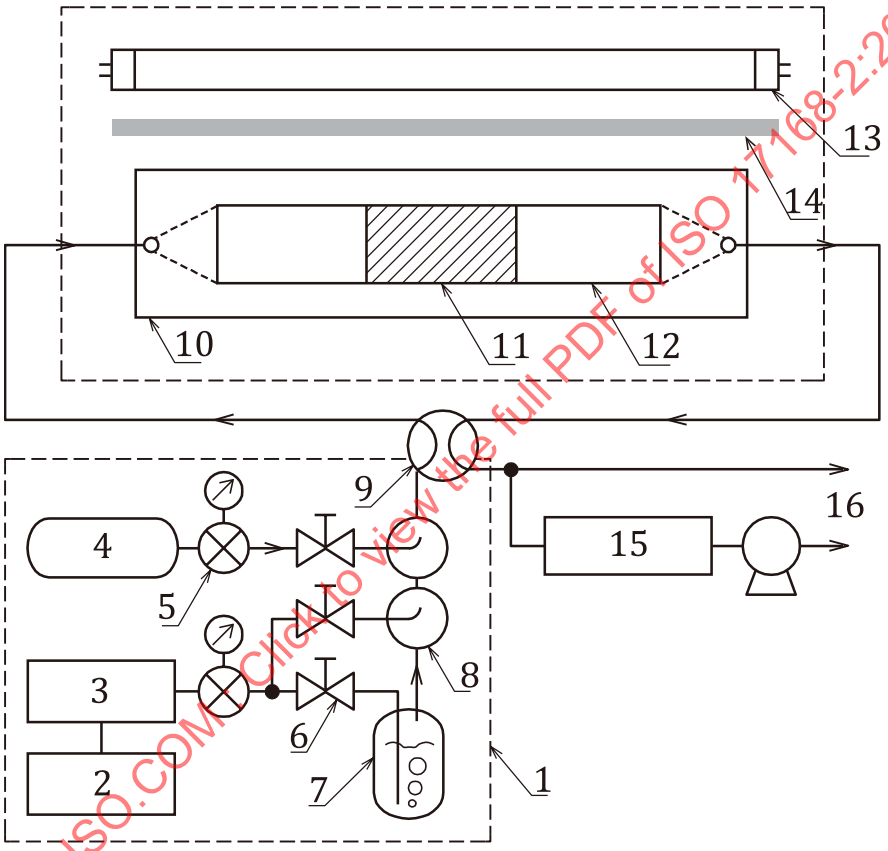
This document deals with the development, comparison, quality assurance, characterization, reliability and design data generation of photocatalytic materials[1]. The method described is intended to obtain the air-purification performance of photocatalytic materials by exposing a test piece to model polluted air under illumination by indoor-light. Acetaldehyde (CH_3CHO) is chosen as a typical volatile organic compound (VOC) with lower molecular mass and offensive odour[2]. The test piece, placed in a flow-type photoreactor, is activated by indoor-light illumination, and adsorbs and oxidizes gas-phase acetaldehyde to form carbon dioxide (CO_2) and other oxidation products[3]. The air-purification performance is determined from the amount of acetaldehyde removed by the test piece (µmol). The simple adsorption by the test piece (not due to photocatalysis) is evaluated by the tests in the dark. However, some test pieces are very absorbent, and a stable volume fraction of acetaldehyde may not be attained in the designated test time. The photocatalytic activity may depend on the physical and chemical properties of pollutants, mainly due to the adsorption process involved. For a better evaluation of the air purification performance of photocatalytic materials, it is recommended that one or more suitable test methods are combined, as provided in other parts of the ISO 17168 series.

The results of an interlaboratory test are given in Annex A to demonstrate the validity of this test method.

6 Apparatus

6.1 Test equipment

The test equipment enables a photocatalytic material to be examined for its pollutant-removal capability by supplying the test gas continuously, while providing photoirradiation to activate the photocatalyst. It is the same as that used in a test method for the removal of nitric oxide (see ISO 17168-1) and consists of a test gas supply, a photoreactor, a light source, a UV sharp cut-off filter and pollutant measurement equipment. Since low-volume fractions of pollutants are to be tested, the system shall be constructed with materials of low adsorption and resistant to ultraviolet (UV) radiation. An example of a testing system is shown in Figure 1.



Key

1	test gas supply	9	four-way valve
2	air compressor	10	photoreactor
3	air-purification system	11	test piece
4	standard gas (pollutant)	12	airtight optical window
5	pressure regulator with a gauge	13	light source
6	mass-flow controller	14	sharp cut-off filter
7	humidifier	15	analyser
8	gas mixer	16	vent

Figure 1 — A schematic of the testing equipment

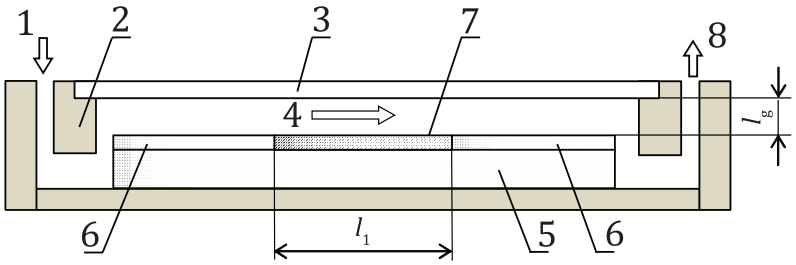
6.2 Test gas supply

The test gas supply provides air polluted with model contaminant at a predetermined concentration, temperature and humidity, and supplies it continuously to the photoreactor. It consists of flow

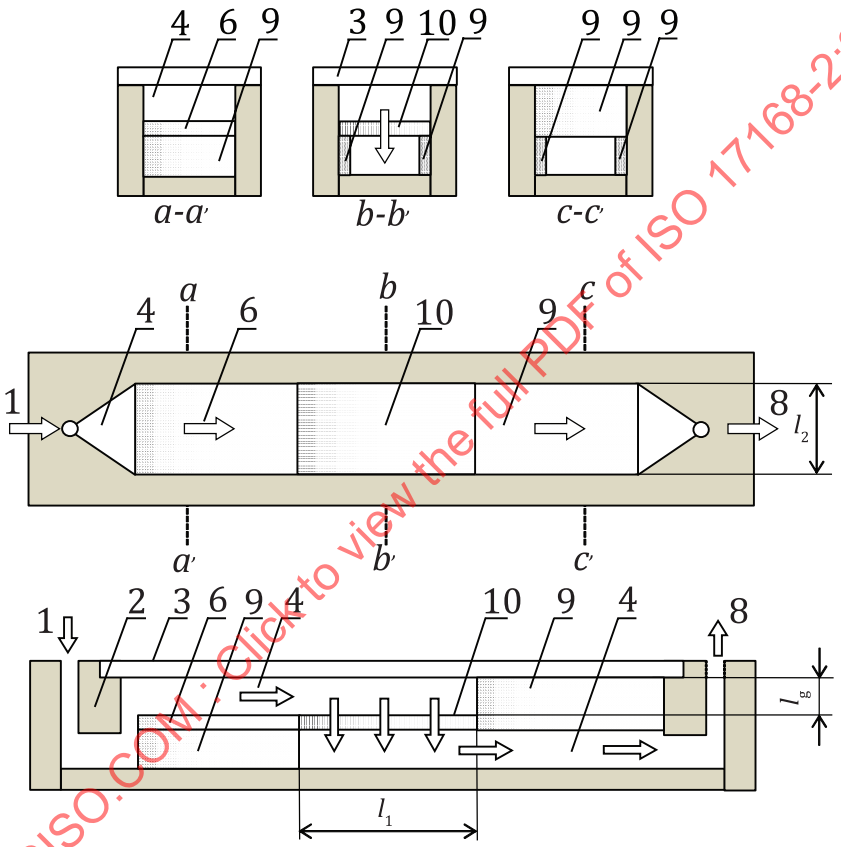
regulators, a humidifier, gas mixers and so on. The flow rate of each gas should be within 5 % of the designated value, which is easily attained by using thermal mass-flow controllers with knowledge of temperature and gas type at calibration in accordance with ISO 6145-7. The expression of gas flow rate in this document is that converted to the standard state (0 °C, 101,3 kPa). Typical capacities of flow controller for pollutant gas, dry air and wet air are 100, 1 000 and 1 000 ml/min, respectively. The standard acetaldehyde gas before dilution, normally balanced with nitrogen in a cylinder, shall have a volume fraction of 50 µl/l to 250 µl/l. Synthetic air (N_2 + O_2, such as supplied in cylinders) shall be used for dilution when the CO_2 from acetaldehyde is also measured.

6.3 Photoreactor

The photoreactor holds a planar test piece within a 50 mm-wide trough, with its surface parallel to an airtight optical window for photoirradiation. The reactor shall be fabricated from materials that adsorb little test gas and withstand irradiation of near-UV light. The test piece shall be separated from the window by a 5,0 mm ± 0,5 mm-thick air layer. The test gas shall pass only through the space between the test piece and the window. This gap shall be accurately set up according to the thickness of the test piece, for example by using height-adjusting plates with different thicknesses, as shown in Figure 2 a). When a filter-type material is tested, an alternative type of test-piece holder shall be used, which holds the test piece while allowing the test gas to pass through the cells of the filter under illumination [Figure 2 b)]. Quartz or borosilicate glass that absorbs minimal light at wavelengths longer than 300 nm should be used for the window.



a) For flat test pieces



b) For filter-type test pieces

Test piece length l_1	Test piece width l_2	Air layer thickness l_g
99,0 ± 1,0 mm	49,0 ± 1,0 mm	5,0 ± 0,5 mm

Key

1 test gas inlet
2 baffle
3 airtight optical window
4 flow channel
5 height-adjusting plate
6 auxiliary plate
7 test piece (flat-type)
8 test gas outlet
9 test piece holder
10 test piece (filter-type)

Figure 2 — Cross-sectional views of photoreactor

6.4 Light source

A cool white halophosphate fluorescent lamp and a UV sharp cut-off filter as specified in ISO 14605 shall be used. The test piece shall be illuminated uniformly through the window by the light source. When testing honeycomb-form photocatalysts, the light source shall illuminate one face of the test piece. A light source that requires warming up shall be equipped with a shutter. The distance between the light source and the reactor shall be adjusted so that the illuminance at the test piece surface is 6 000 lx ± 300 lx. The illuminance along the length of the test piece shall also be constant within ± 5 %. The illuminance shall be measured with an illuminance meter which conforms to ISO 14605. The reactor and light source shall be shielded from external light. The parts around the light source, such as luminaire and shielding device, shall have small reflectance, or flat spectral reflectance over the wavelength range of indoor light.

6.5 UV sharp cut-off filter

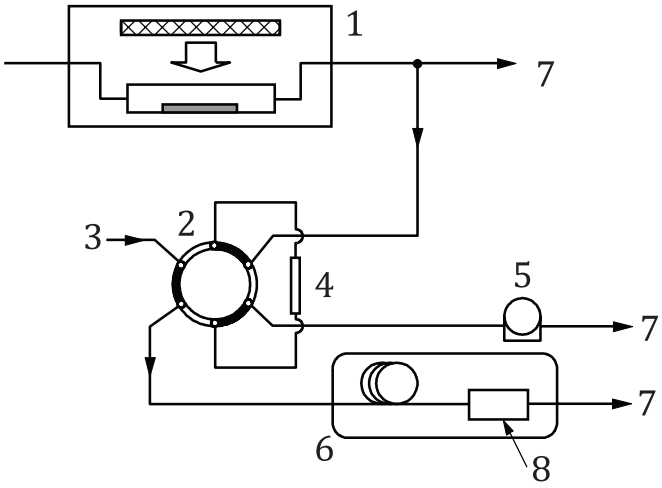
The UV sharp cut-off filter shall remove a small amount of UV light radiated from the light source. The transmittance of the UV sharp cut-off filter shall be less than 0,1 % (wavelength < 365 nm), less than 1 % (at 380 nm) and higher than 80 % (400 nm < wavelength < 780 nm), and the wavelength where the transmittance is half of the average transmittance between 400 nm and 780 nm is located at 390 nm ± 5 nm.

6.6 Analytical system for acetaldehyde

The concentration of acetaldehyde shall be determined by gas chromatography or 2,4-dinitorphenylhydrazine-derivatised high-performance liquid chromatography (DNPH-HPLC).

In the case of gas chromatography, either packed column or capillary column can be used as long as it can separate lower organic compounds. The detection shall be made by either flame ionization detector (FID) or photoionisation detector (PID). The test gas is sampled with a gas-tight syringe. However, use of a six-way valve is recommended for reproducible and automatic sampling. The flow diagram when a six-way valve is used is shown in Figure 3. A small sampling pump continuously ventilates the metering tube with the test gas. The pump is stopped when the test gas is sampled by switching the six-way valve. The volume of the metering tube is typically 0,5 ml, but it shall be determined by the sensitivity of the analytical system.

For the DNPH-HPLC method, the reagents, equipment and procedure as specified in ISO 16000-3 shall be used.



Key

1 photoreactor
2 six-way valve
3 carrier gas
4 metering tube
5 sampling pump
6 gas chromatograph
7 vent
8 FID

Figure 3 — Gas sampling system

6.7 Analytical system for CO_2

Concentration of CO_2 shall be determined using a non-dispersive infrared CO_2 analyser or a gas chromatograph with a methaniser furnace. Calibration of the system shall be done according to ISO 4224. In the case of gas chromatography, the test gas shall be sampled as described in 6.4.

7 Test piece

The test piece shall be a flat material or a honeycomb filter 49,0 mm ± 1,0 mm wide and 99,0 mm ± 1,0 mm long. It may be cut to these dimensions from a larger bulk material or coated sheet, or may be specially prepared for the test by coating a pre-cut substrate. The thickness of the test piece shall ideally be less than 5 mm in order to minimize the contribution from the side faces. If thicker test pieces are to be tested, the side faces shall be sealed with an inert material before testing. The honeycomb test piece shall not be thicker than 20 mm.

8 Procedure

8.1 General aspects

The test procedure consists of pre-treatment of a test piece, adsorption process in the dark, and measurements of removal of acetaldehyde and formation of CO_2 under photoirradiation. An example of concentration change of acetaldehyde and CO_2 during the test is shown in Figure 4. The measurement of CO_2 may not always be feasible for some test pieces. Some test pieces may not give accurate removal of acetaldehyde due to lower photocatalytic activity. In this case, loading of acetaldehyde per test piece can be reduced following the procedure in Clause 10.

8.2 Pretreatment of test piece

8.2.1 The test piece shall normally be pretreated according to the procedures in 8.2.2 and 8.2.3, in this order. When it is anticipated that the test piece has hydrophobic contamination, 8.2.3 may be followed by 8.2.2. The procedure in 8.2.2 can be omitted if it causes damage to the test piece. If the test pieces are not to be tested immediately after this pretreatment, they shall be kept in an airtight container.

8.2.2 Immerse the test piece in deionized water for 2 h or more, remove it and air-dry at room temperature. The test piece may be dried by heating within a temperature range that does not cause physical and chemical changes to the test piece (maximum 120 °C). Dryness is confirmed when a constant mass is reached. The method of drying and any observations, such as the appearance of sediment in the wash water, shall be recorded.

8.2.3 Irradiate the test piece with an ultraviolet lamp for at least 12 h (up to 24 h) to decompose residual organic matter on the test piece. The UV irradiance at the sample surface shall be high enough to secure complete decomposition of organic matter (10 W/m^2 – 20 W/m^2).

8.3 Preparation for the test

8.3.1 Adjust the test gas supply beforehand so that it can stably supply the test gas containing 5,0 µl/l ± 0,25 µl/l of acetaldehyde and 1,56 % ± 0,08 % of volume fraction of water vapour at 25,0 °C ± 2,5 °C. This water-vapour volume fraction is equivalent to a relative humidity of 50 % at 25 °C. The relative humidity shall be measured using a hygrometer (with accuracy of ± 3 % RH) that has been calibrated by a method traceable to a certified reference standard. Adjust the flow regulator so that the flow rate at the inlet of the reactor is 1,0 l/min (0 °C, 101,3 kPa). Measure and record the illuminance from the light source at the surface of the test piece.

8.3.2 Place the test piece in the centre of the photoreactor and attach the glass window after adjusting the air layer between the test piece and the window to a thickness of 5,0 mm ± 0,5 mm. If necessary, height-adjusting plates are used for this purpose, and adjusting the height of the test piece before and after to be within 1,0 mm difference based on the top of the test piece. Check that the reactor is sealed by visual examination of the sealing material, such as an O-ring to tightly connect to the glass window.

8.3.3 Place the UV sharp cut-off filter at the space between the light source and the photoreactor.

8.4 Pretest

When the concentration of acetaldehyde is determined by the DNPH-HPLC method, the concentration cannot be obtained instantaneously. Therefore, the time of the adsorption of acetaldehyde reaching saturation in dark conditions cannot be confirmed during the test. For this reason, the following pretest shall be carried out. If the concentration is determined by gas chromatography and the time for saturation can be confirmed during the test, there is no need for the pretest.

After pretreatment of the test piece in 8.2 and preparation for the test in 8.3, introduce the test gas into the reactor. Measure the concentration of acetaldehyde under dark conditions every 15 min. When the concentration of acetaldehyde exceeds 90 % of the supply gas concentration for the first time, then that time and the concentration at that time are defined as the time of the dark conditions and concentration of the dark conditions, respectively. When the concentration of acetaldehyde is still less than 90 % after 90 min, then this document shall not apply.

8.5 Test of acetaldehyde removal and CO_2 conversion

8.5.1 In order to reduce the concentration of CO_2 in zero calibration gas, carry out the test as follows using synthetic air in a gas cylinder with less than 0,1 µl/l CO_2.

8.5.2 Position the test piece according to 8.3. When the test piece used at pretest is reused, pretreatment described in 8.2 shall be done again.

8.5.3 Supply enough air that does not contain CO_2 into the photoreactor to purge CO_2 from the system.

NOTE The flow rate of 1,0 l/min is indicative. The higher the flow rate is, the faster the CO_2 in the system can be removed.

8.5.4 Supply zero calibration gas with 1,56 % concentration of water vapour at 25,0 °C ± 2,5 °C and measure the concentration of CO_2. Make sure the concentration of CO_2 is low and stable. The change of CO_2 concentration in 30 min shall be no higher than 0,1 µl/l. Measure the concentration of CO_2 under illumination. Then turn the light off and measure the concentration of CO_2 again. If the difference between CO_2 concentration with light on and light off is less than 1 µl/l, move forward to the next step. If a large amount of CO_2 is observed to generate when the light is turned on, it is conceivable that the test piece has not been well pretreated and is contaminated with organic matter, or the binder in the test piece has been decomposed by UV irradiation. When the previously cited condition does not meet even pretreatment of enough UV irradiance and so on, then the CO_2 conversion shall not be measured.

8.5.5 Carry out the measurement using the procedure specified in 8.3.1.

8.5.6 If the pretest has been done, supply the test gas into the photoreactor until the time of the dark conditions (adsorption) which has been checked beforehand (if the time is less than 30 min, supply for 30 min) and measure the concentration of CO_2. If the pretest has not been done, do as follows. First, supply the test gas into the photoreactor and record the change in the concentrations of acetaldehyde and CO_2 under dark conditions to examine the adsorptivity of the test piece. When the concentration of acetaldehyde exceeds 90 % of the supply gas concentration for the first time, the concentration at the time is defined as the concentration of the dark conditions. When the concentration of acetaldehyde is still less than 90 % after 90 min, then this document shall not apply. If the requirement mentioned above is satisfied, it is possible to continue the dark conditions for the purpose of increasing the concentration of the dark conditions. The concentration of CO_2 measured for the last 30 min (more than 2 points) is to be the concentration of CO_2 ($\phi_{CO2,\,Dpre}$) under the dark conditions before indoor light irradiation.

8.5.7 Maintain the gas flow and commence irradiation of the test piece, then record the concentration of acetaldehyde and CO_2 under photoirradiation for 3 h continuously. As photocatalytic decomposition of acetaldehyde occurs, the concentration of acetaldehyde lowers and the concentration of CO_2 grows, as shown in Figure 4, and they become stable in time. Continuous measurement of the concentrations is desirable. However, if there is a limit to the number of measurements, at least one point measurement within 1 h shall be carried out. In addition, more than three point measurements shall be done in the last 1 h (120 min to 180 min after irradiation). The concentration of acetaldehyde (ϕ_A) to be used for calculation of removal rate and the concentration of CO_2 ($\phi_{CO2,L}$) is to be the mean value (more than 3 points) of the concentration measured during the last 1 h.

8.5.8 Stop photoirradiation, bring back to the dark conditions and measure the concentration of CO_2. After the concentration of CO_2 has settled, the mean value (more than 2 points) during this 30 min period is reported as the CO_2 concentration under dark conditions after light irradiation ($\phi_{CO2,Dpost}$).

8.5.9 Stop test gas supply to the reactor, and remove the test piece from the reactor.

8.6 Test of acetaldehyde removal (when CO_2 concentration cannot be measured)

8.6.1 Pretreat the test piece and prepare for the test according to 8.2 and 8.3.

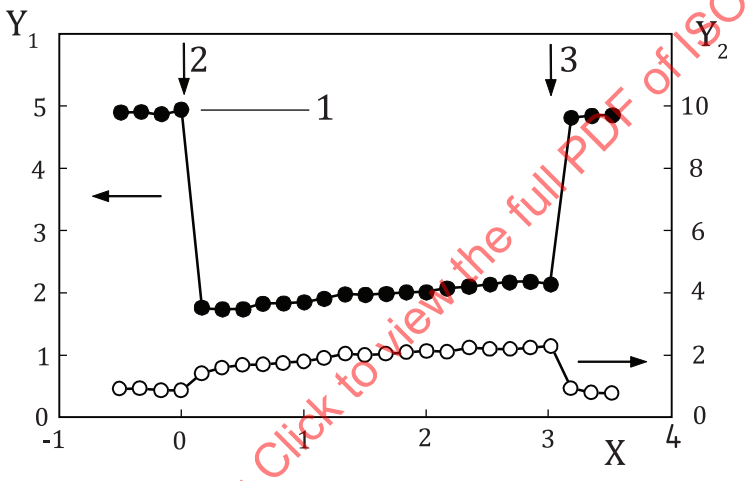
8.6.2 When the pretest (8.4) has been done, allow the test gas to flow into the photoreactor until the time of the dark conditions which had been determined beforehand. If the pretest has not been done, do as follows. Supply the test gas to the photoreactor under dark conditions, then measure the concentration

of acetaldehyde until it exceeds 90 % of the supply gas concentration. At this time the concentration is defined as the concentration of the dark conditions. If the concentration of acetaldehyde is still less than 90 % after 90 min, then this document shall not apply.

8.6.3 Maintain the gas flow and commence irradiation of the test piece, then record the concentration of acetaldehyde under photoirradiation for 3 h. When photocatalytic decomposition of acetaldehyde occurs, the concentration lowers, as shown in Figure 4, and becomes stable in time. It is preferable to measure the concentration of acetaldehyde continuously. However, if the number of measurements is limited due to the analytical method (i.e. DNPH-HPLC), more than one measurement shall be done at an interval of 1 h or less. In addition, more than three measurements shall be done for the last 1 h (120 min to 180 min after photoirradition). The concentration of acetaldehyde to be used for calculation removal rate is the mean value of the concentration measured during the last 1 h.

8.6.4 Stop photoirradiation and confirm that the concentration of acetaldehyde returns to supply gas concentration (5,0 µl/l).

8.6.5 Stop gas supply to the reactor and take the test piece out of the reactor.



Key

1 acetaldehyde feed level
2 lights on
3 lights off
X time (h)
Y_1 acetaldehyde concentration (µl/l)
Y_2 CO_2 concentration (µl/l)

Figure 4 — Typical trace of acetaldehyde and CO_2 concentration during the test operation

9 Calculation

9.1 Calculation method

The test results shall be calculated as follows. The calculated values are usually rounded to one decimal place in accordance with ISO 80000-1. The flow rate of test gas f is 1,0 (l/min) normalized for 0 °C, 101,3 kPa.

9.2 Removal percentage and removed quantity of acetaldehyde

If ϕ_A does not satisfy Formula (1), i.e. the difference between acetaldehyde concentrations under dark conditions and under photoirradiation is less than 5 % of the acetaldehyde concentration supplied, this test method shall not be applied. The removal percentage of acetaldehyde is calculated by Formula (2). When R is below 5 % or more than 95 %, the removal percentage shall be expressed as "below 5 %" or "more than 95 %", respectively, for uncertainty reasons. Then, the removed quantity per hour is calculated by Formula (3). Similarly, when n_A is below 5 % or more than 95 %, the removed quantity per hour shall be expressed as "below 5 %" or "more than 95 %", respectively.

$$\phi_A \leq \phi_{AD} - \phi_{A0} \times 0{,}05 \tag{1}$$

$$R_A = \frac{\phi_{A0} - \phi_A}{\phi_{A0}} \times 100 \tag{2}$$

$$n_A = R_A \times \frac{\phi_{A0} \times f \times 60}{100 \times 22{,}4} \tag{3}$$

where

R_A is the removal percentage, by test piece, of acetaldehyde (%);

ϕ_A is the volume fraction of acetaldehyde at the reactor exit (µl/l);

ϕ_{AD} is the volume fraction of dark conditions (µl/l);

ϕ_{A0} is the supply volume fraction of acetaldehyde (µl/l);

n_A is the removal quantity, by test piece, of acetaldehyde (µmol);

f is the flow rate of test gas converted into that at the standard state (0 °C, 101,3 kPa) (l/min).

9.3 Conversion to CO_2

The volume fraction of CO_2 formed by UV irradiation is calculated by Formula (4), and then the CO_2 conversion R_{CO2} shall be calculated by Formula (5). When R_{CO2} is either less than 5 % or more than 95 %, it shall be expressed as "below 5 %" or "more than 95 %", respectively. The quantity of CO_2 converted (n_{CO2}) is calculated by Formula (6). When R_{CO2} is either less than 5 % or more than 95 %, n_{CO2} is calculated by assigning 5 or 95 for R_{CO2}, respectively.

$$\phi_{CO2} = \phi_{CO2,L} - \phi_{CO2,D} \tag{4}$$

$$R_{CO2} = \frac{\phi_{CO2} \times 100}{2 \times \phi_{A0}} \tag{5}$$

$$n_{CO2} = R_{CO2} \times \frac{2 \times \phi_{A0} \times f \times 60}{100 \times 22{,}4} \tag{6}$$

where

ϕ_{CO2} is the CO_2 volume fraction generated by indoor light irradiation (µl/l);

$\phi_{CO2,L}$ is the CO_2 volume fraction at the reactor exit under indoor light irradiation (µl/l);

$\phi_{CO2,D}$ is the CO_2 volume fraction at the reactor exit under dark conditions (µl/l);

R_{CO2} is the conversion from acetaldehyde to CO_2 (%);

n_{CO2} is the quantity of CO_2 converted from acetaldehyde per hour (µmol/h).

The CO_2 concentration under dark conditions shall be the mean value before and after the indoor light irradiation period as calculated by Formula (7). It shall not change by 1,0 µl/l or more before and after indoor light irradiation.

$$\phi_{CO2,D} = \frac{\phi_{CO2,Dpre} + \phi_{CO2,Dpost}}{2} \quad (7)$$

where

$\phi_{CO2,Dpre}$ is the CO_2 volume fraction in the dark before indoor light irradiation (µl/l);

$\phi_{CO2,Dpost}$ is the CO_2 volume fraction in the dark after indoor light irradiation (µl/l).

10 Test method for test pieces with lower performance

When the removal percentage is less than 5 % and a more certain result is demanded, the number of test pieces and the flow rate of test gas may be altered as shown in Table 1. However, the removal quantity of acetaldehyde and conversion to CO_2 which appears in the test report shall be half of the values calculated from Formulae (3) and (6), and shall use a flow rate of 0,5 l/min. When the test conditions are altered, the time of adsorption (dark conditions) shall be confirmed at the altered test conditions.

Table 1 — Alternative test conditions

Alterable test conditions	Value after change
Flow rate of test gas	0,5 l/min ± 0,025 l/min
Number of test pieces	Two pieces in series (surface of 50 mm × 200 mm)

11 Test report

The test report shall include the reporting provisions of ISO/IEC 17025 and the following information. Items g), h) and i) shall be reported for each test.

a) the name and address of the test establishment;

b) the date of the test, a unique identification of the report and of each page, customer name and address, signatory of the report;

c) a reference to this document, i.e ISO 17168-2;

d) date of test, temperature, relative humidity;

e) description of the test piece (e.g. material, size, shape);

f) description of test equipment (e.g. specifications);

g) testing conditions (e.g. kind of pollutant gas, supply concentration, water-vapour concentration, flow rate, kind of light source, kind of UV sharp cut-off filter, illuminance, analyser and radiometer used, condition of pretreatment, modification under Clause 10);

h) the amount of acetaldehyde removed and CO_2 formed during the last 1 h, removal percentage of acetaldehyde (optional) and conversion to CO_2 (optional); if the test or CO_2 measurement is not valid, the reasons for that;

i) any comments or observations, such as a change in the test piece noticed during the test.